The Geology of an Area North-east of Cudgegong, New South Wales

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In an area to the north-east of Cudgegong, N.S.W. a strip of Early and Late Devonian sediments and volcanics is faulted to the west against Late Silurian strata, mostly of the dacitic and rhyolitic Windamere Volcanics. To the east the Devonian strata are unconformably overlain by the Permian Rylstone Tuff and Megalong Conglomerate.

The Devonian consists of two portions with an unconformable contact. The Early Devonian sequence consists of the Yellowman's Creek beds (new name, oldest Devonian unit), Roxburgh Formation, Riversdale Volcanics and Carwell Creek beds. The brachiopod fauna present in the Yellowman's Creek beds is indicative of a Lochkovian age whereas *Buchanathyris* suggests a Zlichovian age for the Carwell Creek beds; the intervening beds are interpreted as being Lochkovian to Pragian. Late Devonian strata are represented by the Buckaroo Conglomerate (oldest), Bumberra Formation and Lawsons Creek Shale (youngest).

The region was affected by the Mid-Devonian Tabberabberan Orogeny, producing an angular unconformity between Early and Late Devonian strata. The Carboniferous Kanimblan Orogeny produced NW-SE trending faults and folds. Permian strata are undeformed.

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INTRODUCTION

Late Silurian to Permian strata crop out in an area to the immediate NE of the former site of the township of Cudgegong, in the Central Tablelands of N.S.W. Cudgegong, now becoming submerged beneath the waters of Lake Windamere, was located approximately 35 km to the SE of Mudgee and about 260 km NW of Sydney (Fig. 1).

The stratigraphic sequence of the study area is listed in Fig. 2 and includes extensive units of both Early and Late Devonian age as well as subordinate Late Silurian and Permian units.

The pre-Permian rocks were deposited on the Capertee Geanticline of Packham (1960), where Silurian and Devonian strata 'occur *inter alia* in fold structures trending to approximately 140°' (Wright, 1967). As can be observed in Fig. 3, the strata within the study area occupy the easternmost of two fault-bounded blocks in the Mudgee region, whereas the Silurian Windamere Volcanics are part of the belt of strata separating the two fault blocks. These strata are overlain unconformably by the Permian Rylstone Tuff and Megalong Conglomerate of the Sydney Basin sequence.

STRATIGRAPHY

Windamere Volcanics

The only Silurian unit cropping out in the study area is the Late Silurian Windamere Volcanics of Pemberton (1980b). This unit occupies a very minor portion of the study area, cropping out in the extreme west (see Fig. 2) but extending to the NW for approximately 30 km along strike (Pemberton, 1980b). In the study area this unit abuts an extensive suite of Devonian sediments, the contact being a NNW-SSE trending fault (the Cudgegong Fault of Game, 1934).

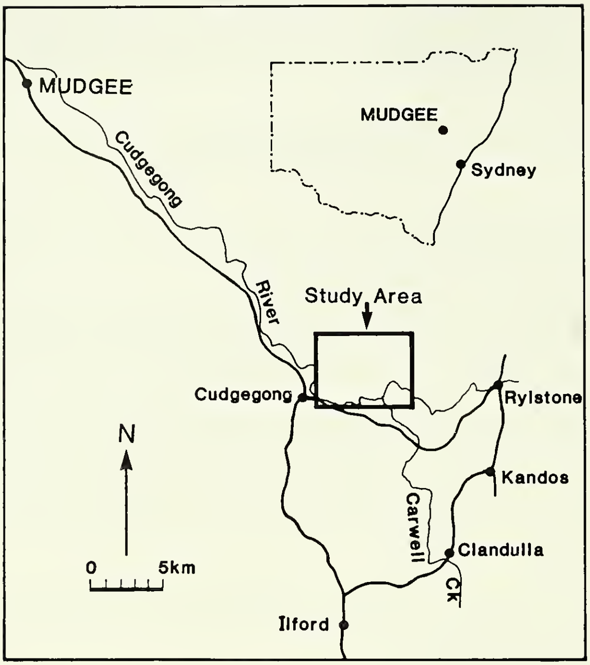


Fig. 1. Locality map showing position of the study area in relation to Mudgee (modified from Offenburg *et al.*, 1971).

Petrography

In the study area the Windamere Volcanics consist of a lower blue-green, massive, fine grained, porphyritic dacite with up to 4.3% embayed quartz and 5.7% albite phenocrysts set in a cherty matrix. Occasional bands of angular to subrounded dacite clasts occur throughout, indicating phases of reworking of the sequence.

Overlying the lower horizon is a white, flow-layered, porphyritic rhyolite lava. Most of the quartz phenocrysts are anhedral to subhedral and up to 2.5 mm in size. Phenocrysts of orthoclase up to 0.9 mm are also present but in trace amounts. The phenocrysts are set in a cherty matrix of probable quartzo-feldspathic composition. Pemberton (1980b) has reported the presence of similar horizons at varying stratigraphic levels elsewhere in the Windamere Volcanics.

Yellowman's Creek Beds

The name Yellowman's Creek beds is introduced for poorly outcropping greenish-brown coloured shale and subordinate grey, dolomitic micritic limestone, outcropping between GR 654 662 and GR 658 696 (see Fig. 2), with a thickness exceeding 165 m. The base of the unit is not exposed in the study area, the unit abutting the Windamere Volcanics further to the west along the Cudgegong Fault. The upper contact of the unit with the Roxburgh Formation is apparently conformable but not well exposed. The representative section of this unit is between GR 657 677 and GR 657 672. This section represents the best outcrop of the Yellowman's Creek beds (but unfortunately consists entirely of shale, the limestone constituting only a very minor proportion of the unit and being restricted to very poorly exposed areas at GR 656 675, see Fig. 2), and passes sharply southwards into the sandstones of the Roxburgh Formation.

Petrography

Shales of the Yellowman's Creek beds are brownish-green in colour and are composed predominantly of chlorite, muscovite, quartz and hematite, with minor detrital biotite. Grain sizes range up to 0.07 mm, the majority being much smaller, with the larger size range being almost entirely quartz grains.

Limestones are dark grey, strongly stylotized, pellet-bearing, packed biomicrite (after the terminology of Folk, 1962), consisting dominantly of ferroan calcite with abundant patches of late diagenetic ferroan dolomite. Areas of silicification are restricted to the cores of the diagenetic dolomite patches and to a lesser extent the shells of brachiopods.

Environment of Deposition

Very little information can be gained about the environment of deposition of this unit due to poor outcrop. The presence of a marine fauna, micritic limestones and the dominance of shale is however indicative of a very quiet water, marine environment.

Fauna and Age

The only fauna recovered from the Yellowman's Creek beds is from the isolated limestone pods, and includes the silicified brachiopods *Atrypa* sp., *Cyrtina* sp., *Howellella* sp., *Eoschuchertella* sp., *Skenidioides* sp., *Dolerorthis* sp., *Anastrophia* sp., *Dicaelosia* sp., as well as pentamerids, other dalmanellids, chonetids and the coral *Rhizophyllum* sp. Identifications were made by Dr A. J. Wright who states that the presence of *Cyrtina* is indicative of a Devonian age. *Eoschuchertella*, *Anastrophia*, and *Skenidioides* have been reported in Lochkovian (Early Devonian) sediments elsewhere in N.S.W. (Savage, 1971), and these indicate this age for the Yellowman's Creek beds.

Roxburgh Formation

The Roxburgh Formation (Pemberton, 1980a) is developed as a northerly-thinning wedge dominated by quartzarenite, sublitharenite and litharenite with minor conglomerate and rare limestone, with a total thickness of 625 m.

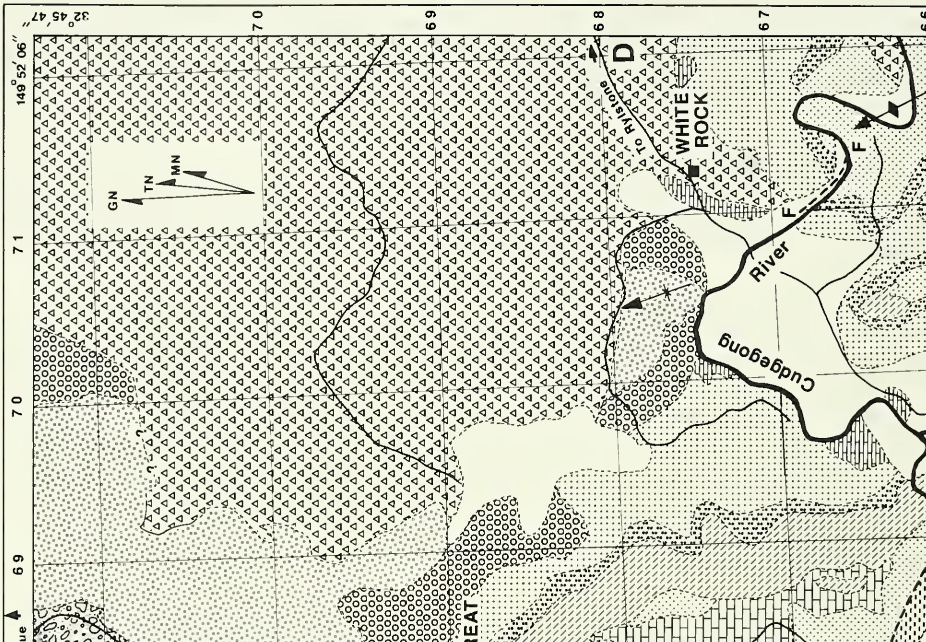
The lower contact of the Roxburgh Formation is best exposed in the vicinity of GR 657 672 where it is apparently conformable with the Yellowman's Creek beds. However, whereas the contact is quite sharp in the given area it is generally poorly exposed in the remainder of the study area. The Roxburgh Formation is conformably overlain by acid volcanics and volcarenites of the Riversdale Volcanics. The nature of this boundary has been described from better outcrops to the south by Pemberton (1980a). In the vicinity of GR 673 661 the Roxburgh Formation passes directly into the Carwell Creek beds, the Riversdale Volcanics being absent. However due to a paucity of outcrop in this area the incomplete stratigraphic sequence remains unexplained.

Petrography

In the Roxburgh Formation the dominant lithology is very fine- to medium-grained, quartzarenite/sublitharenite containing up to 90% quartz grains with cherty acid volcanic rock fragments being the other major component. These lithologies are predominantly moderately to poorly sorted, texturally submature and display abundant quartz overgrowths.

The conglomerates within the sequence are coarse granule-sized, containing abundant pebble-sized clasts dominated by cherty acid volcanics (up to 73%) as well as up to 11.3% angular quartz grains. Texturally the conglomerates are loosely packed, poorly sorted, texturally immature and extensively silica cemented.

The limestone is fine-grained, predominantly grey-coloured, and unfossiliferous with abundant red veins of hematite. The lithology shows extensive growth of neo-


WHITE ROCK
RETREAT
To Rylstone
To Lue
Cudgegong
River
GN
TN
MN
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149°52'06"
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32°45'47"
32°45'51"

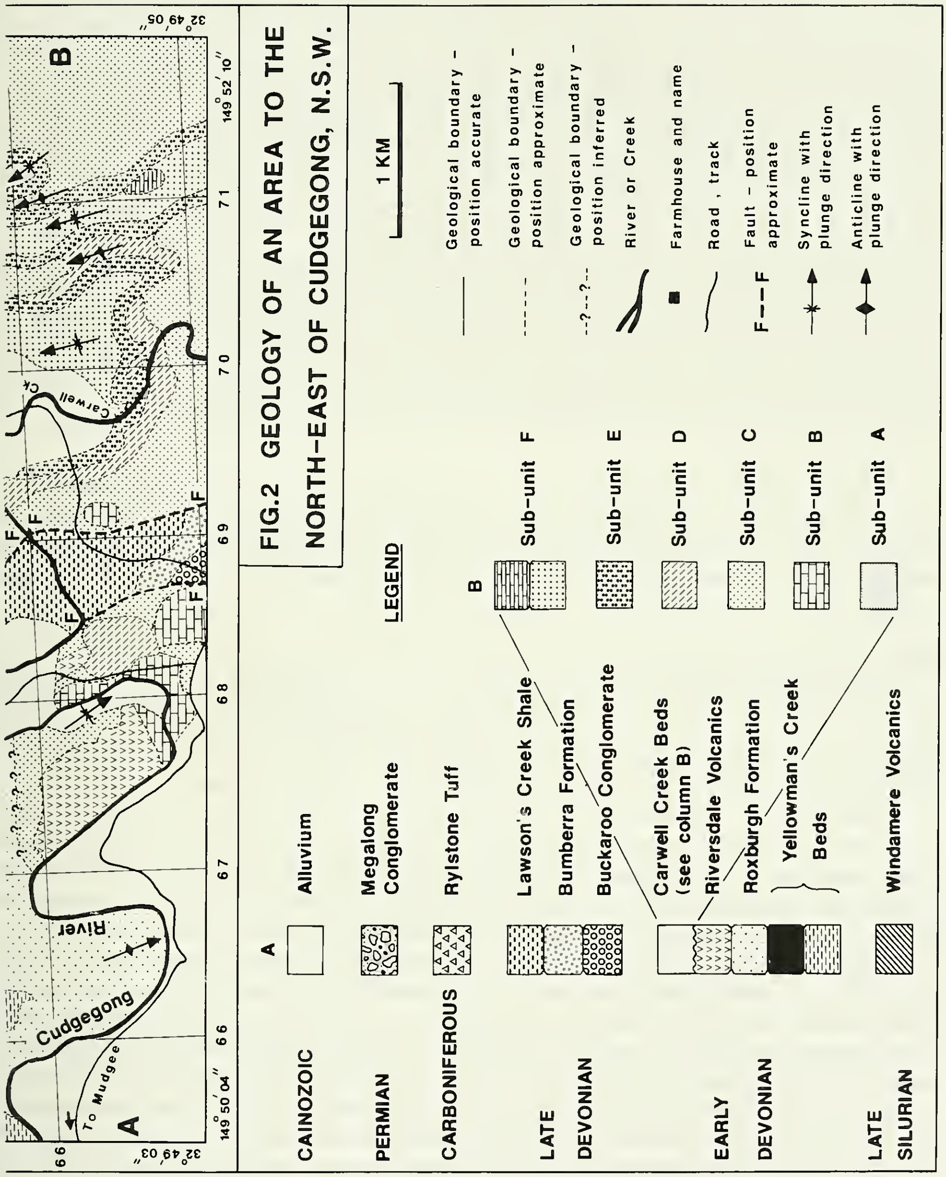

FIG.2 GEOLOGY OF AN AREA TO THE NORTH-EAST OF CUDGEGONG, N.S.W.

morphic spar due to diagenesis. It has been heavily dolomitized, being up to 98% late diagenetic dolomite. The dolomitization postdates the neomorphic recrystallization.

Environment of Deposition

The Roxburgh Formation is subdivided into three main lithotypes; these are A) thinly parallel laminated to rarely cross-bedded sandstone beds up to 40 cm thick, B) massive sandstones up to 40 cm thick, with occasional angular shale clasts, C) rare, thin, lenticular shales. Conybeare and Crook (1982) suggested that the prsence of shale clasts is indicative of several depositional environments, these being fluvial, tidal flats and channels, neritic, and the bathyal-abyssal environments. A marine environment is indicated by the presence of fragments of crinoids and bryozoans. Tidal flat/channel environments are rejected due to the absence of desiccation features, bioturbation, and channel structures, as well as the dominance of sand in the sequence. Similarly the bathyal-abyssal alternatives can be discounted as neither turbidites nor laterally extensive muds are present. A neritic environment is therefore proposed for the Roxburgh Formation, its sediments most closely resembling the sandy facies of Reineck and Singh (1980). This would indicate a lower shore face environment, with maximum water depths of 15-20 m, as Reading (1978) suggested that above this depth the deposition of shales is affected by fair weather wave activity. The change from the shales and micrites of the Yellowman's Creek beds to the sandstones of the Roxburgh Formation therefore probably represents a shallowing of water depths.

Fauna and Age

The fauna of the Roxburgh Formation is very sparse. However, Pemberton (1980a) reported the presence of brachiopods, including *Iridistrophia*, *Howellella*, and *Delthyris*, that are indicative of an Early Devonian age. As the underlying unit is Lochkovian and the overlying Carwell Creek beds Zlichovian, an approximate Pragian age is inferred for this unit.

Riversdale Volcanics

Conformably overlying the sediments of the Roxburgh Formation is a suite of rhyolitic and dacitic lava, tuff and volcarenite, up to 320 m thick. The unit was first described by Wright (1966) as the Riversdale Rhyolite but was later designated by Offenburg *et al.* (1971) as the Riversdale Volcanics.

Petrography

The Riversdale Volcanics can be subdivided into a number of distinct lithologies. The oldest is white flow-layered rhyolite containing up to 45.2% anhedral quartz grains (commonly embayed), 1.6% euhedral orthoclase and 4.8% euhedral Na-plagioclase phenocrysts, set in a very fine-grained quartzo-feldspathic groundmass.

The overlying lithology varies from pink to green, is massive, porphyritic and very fine-grained. In the green (chloritic) lithology anhedral to euhedral quartz grains vary in abundance up to 4.7% and up to 3.5 mm in size; subhedral to euhedral plagioclase phenocrysts up to 2.5 mm in size comprise up to 10.3% of the lithology, while orthoclase as subhedral to euhedral grains up to 2 mm in size can constitute up to 12.7% of the rock. The pink (hematitic) lithology is a lateral equivalent of the green rock type and contains up to 3.5% anhedral quartz phenocrysts which vary in size up to 2.5 mm. The other major phenocryst phase is anhedral orthoclase grains up to 0.6 mm in size. The groundmass contains abundant devitrified glass shards. A reworked horizon at the top of the Riversdale Volcanics consists of tightly-packed, poorly-sorted sandstone and conglomerate with clasts generally in the pebble to cobble size range. The lithology is massive and varies between white and purple in colour, with abundant cherty silica cement.

Age

The Riversdale Volcanics are underlain and overlain by inferred Pragian and Zlichovian rocks respectively. The presence of an unconformity between the Riversdale Volcanics and the overlying Carwell Creek beds is suggested by a discontinuous, apparently reworked volcarenite at the top of the volcanics. This would tend to favour the Riversdale Volcanics being assigned a Pragian age.

Carwell Creek Beds

The Carwell Creek beds (Offenburg *et al.*, 1971) are the youngest and most areally extensive of the Devonian units, occurring over the majority of the central and southeastern portions of the area (between GR 656 712 and 710 650). In the NE of the study area the unit thins in outcrop, being unconformably overlain, to both the east and west, by the Buckaroo Conglomerate.

The Carwell Creek beds are over 1250 m of limestone, litharenite, and conglomerate that can be divided into a number of informal sub-units, as is shown in Fig. 2. The lowermost sub-unit or member (unit A) unconformably overlies the Riversdale Volcanics, often being underlain by discontinuous volcarenite of the volcanic sequence. The upper contact of the Carwell Creek beds is not exposed in the study area, being faulted out in the vicinity of GR 691 652, and overlain with angular unconformity by the southernmost outcrops of Late Devonian strata occupying the major syncline appearing in the NE portion of Fig. 2.

Petrography

Lithologically the Carwell Creek beds are quite varied. These lithologies can be generally grouped into sub-units (see Fig. 2), although each can itself be quite variable, especially the limestones. The following therefore is only a brief summary of the lithologies present, rather than a more detailed description of each.

Sub-unit A is fine- to very fine-grained, buff to cream coloured sandstone with occasional grey limy pods and lenses, especially near the contact with sub-unit B. Scattered throughout are fragments of bryozoans and crinoid ossicles varying between 0.5-1.0 mm in size. The unit is developed at GR 677 685.

Sub-unit B (cropping out between GR 680 679 and 685 672) is dominated by fine-grained, greenish-brown limestone occurring in massive beds up to 15 cm thick. The unit is strongly recrystallized, with primary structures destroyed by the growth of neomorphic spar, the grains varying between 0.09 and 0.22 mm in size. This recrystallized limestone occasionally contains beds of dark grey, fossiliferous, micritic limestone, which appears to be the original texture of the limestones as it lacks neomorphic calcite. Some of these micritic horizons are distinctive in that they contain abundant sericite, giving them a distinctive yellowish coloration, and also in that they contain abundant solitary corals up to 10 cm in size. Discontinuous pods of grey coloured, coarse intrasparrudite also occur in sub-unit B, being present in beds up to 5 m thick. These intrasparrudites are dominated by angular micritic intraclasts with some volcanic rock fragments and occasional fossils. Also present within this sub-unit is a red-brown coloured, highly discontinuous pebble- to boulder-sized conglomerate which is tightly packed, with rounded to subrounded clasts of cherty acid volcanics (very similar to the Riversdale Volcanics), up to 25 cm in size, set in a cherty matrix. A biostromal limestone, present near the base of sub-unit B, contains abundant bulbous stromatoporoids set in a buff coloured, recrystallized matrix.

Sub-unit C is composed of fossiliferous biosparite, and crops out particularly well between GR 688 680 and GR 690 670. It is distinguished by abundant, densely-packed crinoid ossicles and stem segments (up to 3 cm in size) and small to large scale cross-bedded crinoid bearing sandstone. Apart from the crinoid fragments, the rest of the lithology consists dominantly of quartz grains (15.2-22.0%) which are often embayed.

Sub-unit D is composed of grey to brown, fine- to medium-grained litharenite, quartzarenite and sublitharenite, cropping out at GR 682 666, with a maximum thickness of 495 m. The sub-unit is dominated by quartz (40.0-80.3%) with cherty acid volcanic rock fragments constituting up to 45.0%, and is silica cemented.

Cropping out at GR 691 672 is sub-unit E, which is massive to poorly cross-bedded, reddish-purple, tightly packed, poorly sorted conglomerate with cherty acid volcanic rock fragments set in a coarse matrix. The lithology has a maximum thickness of 45 m.

Massive, light grey, fine- to medium-grained, massive to finely plane-laminated litharenites and well-bedded limestones cropping out at GR 695 674 are referred to here as sub-unit F and have a minimum thickness of 700 m. The litharenites contain lithic clasts dominated by cherty acid volcanics, contain very minor metaquartzite and traces of shale, and are strongly silica cemented. Interbedded within sub-unit F is a discontinuous limestone with a maximum thickness of 18 m, that occurs approximately 140 m above the base of the sub-unit. It is composed of a lower horizon of Folk's (1974) type II limestone with dolomitized micrite, fossiliferous micrite, biomicrite, biopelmicrite and pelmicrite present as well as interbedded shales. Fossils include corals and brachiopods. Above this horizon is a sequence of interbedded, dolomitized biolithite beds (dominated by bulbous stromatoporoids) and unfossiliferous, dolomitized, medium-crystalline carbonate. These two (the lower micritic horizon and the upper biolithite/medium-crystalline horizon) can also be distinguished in that the former is dark grey while the latter is very light grey in colour.

Environment of Deposition

The poor exposure and lack of sedimentary structures in sub-unit A make interpretation of its environment of deposition difficult. However, the presence of bryozoan fragments is indicative of marine conditions, while the calcareous lenses suggest periods of quiet water deposition.

Sub-unit B is lithologically varied, containing extensive, massively bedded micritic limestones, lenses of intrasparrudite, biolithite and conglomerate. The biolithite, the lowermost facies of the sub-unit, is dominated by bulbous stromatoporoids. Wilson (1975) stated that a bulbous shape is an adaptation to prevent fine sediment settling out on the surface of the stromatoporoid; as forms with such a shape are usually found in quiet water, below wave base or in shallow protected back reef areas. The lensoidal intrasparrudite horizons contain abundant, angular, pellet-sized micrite clasts. Intraclasts are deposited either on supratidal flats or in subtidal channels (Shinn, 1983). Intraclasts originating from subtidal and intratidal environments are usually composed of grapestone, individual pellets, mudsized particles or fossils (Flugel, 1982), and the micrites present in the sequence lack evidence of exposure. The intraclasts therefore represent material eroded from supratidal flats during storm activity, and deposited into subtidal channels. The co-occurrence of the micrites and intrasparrudite lenses is indicative of water depths less than 20 m (Flugel, 1982; fig. 70) as their association represents deposition above fair weather wave base. The association of the biolithite with these two lithologies would indicate that it too was deposited above wave base, restricting its environment of deposition to either back reef or back bank, indicating a maximum water depth of 5 m (Enos, 1983). The irregular outcrop and highly variable thickness of the conglomerate suggests that it infills hollows in the underlying carbonate, the coarsest material occurring in the thickest section. It is generally poorly sorted, but in the thickest section the largest clasts are restricted to the top and sides of the outcrop,

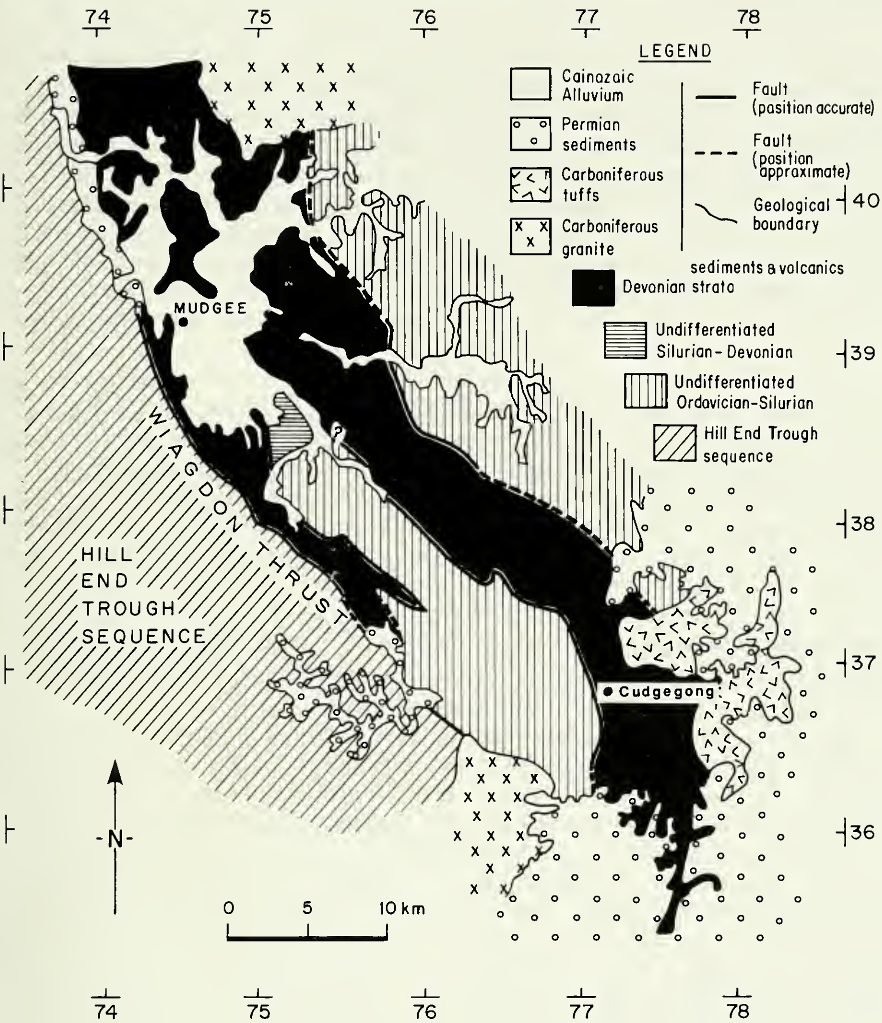

Fig. 3. Regional geology of the Mudgee-Cudgegong area (modified from Offenburg *et al.*, 1971, and Pemberton, 1977, 1980a, and 1980b) illustrating the presence of two faulted blocks of Devonian strata. The grid system appearing on the map is the Australian metric map grid.

suggesting that it is a mass flow deposit derived from an acid volcanic source. The most probable source of this would have been exposed Riversdale Volcanics. A near shore origin for the conglomerate is preferred due to the difficulty in getting clasts up to 25 cm in size into offshore environments.

The sediments of sub-unit C can be divided into three groups on the basis of their sedimentary structures; these being massive beds containing stringers of crinoid ossicles, beds showing fining-upward sequences of crinoidal detritus and thick, cross-bedded horizons composed predominantly of crinoid stem segments up to 3 cm long. The cross-bedded horizons are interpreted as representing nearshore bars, while the sandstones exhibiting fining-upward structures can be explained by pumping of the sediments by storm waves. This association of environments would restrict sub-unit C to the upper shore face.

Sub-unit D is an interbedded sequence of very fine- to medium-grained sandstone beds up to 60 cm thick; either massive (with occasional flat, angular shale clasts up to 4 cm in size) or finely, internally laminated. Rarely interbedded shale horizons up to 5 cm thick are also present. These sediments are almost identical with those of the Roxburgh Formation, and as with that formation the relative lack of cross-bedding, lack of desiccation features, dominance of sand and absence of Bouma sequences indicates a shallow neritic environment. The angular shale clasts within massive beds are interpreted as having been ripped up and deposited during storm activity, the storm waves also disrupting and obliterating sedimentary structures. The plane laminated horizons therefore represent periods of normal sedimentation, while the shale beds indicate that deposition occurred below fair weather wave base, as in the lower shoreface environment of Reineck and Singh (1980).

Sub-unit E is a sequence of poorly bedded and sorted, rarely cross-bedded pebble conglomerates and pebbly sandstones. Collinson and Thompson (1982) indicated several environments in which significant amounts of gravel accumulate, these being river channels, fan deltas, alluvial fans and steep slopes, shorelines, glacial environments and areas associated with volcanoes. Although there is no direct fossil evidence to suggest a marine environment of deposition the association of the unit with marine sediments would suggest a similar origin. There is also no evidence of either Devonian glaciation in the region, or of volcanism contemporaneous with the deposition of the conglomerate. The sheet-like nature of the conglomerate and the absence of fining-upward sequences would then suggest a shoreline deposit, although the presence of tabular cross-bedding and the poorly sorted nature of the sediment preclude a beach environment.

Sub-unit F is primarily a sequence of thickly bedded, massive to finely laminated sandstones (rarely cross-bedded), that are almost identical in appearance with the sandstones of the Roxburgh Formation and sub-unit D of the Carwell Creek beds. Accordingly a lower shoreface environment of deposition is proposed for the sandstones. Interbedded with the siliciclastic sediments of sub-unit F is a discontinuous limestone horizon that is divisible into two sections. The lower 6-7 m consists of thick bedded, micritic limestone interbedded with thin, up to 12 cm thick, shale horizons indicating deposition in quiet water conditions and the abundance of pellets indicating pronounced infaunal activity. It is apparent from the criteria stipulated by Enos (1983) that these lithologies were deposited in a lagoonal environment. The upper section of the limestones contains abundant bulbous stromatoporoids forming biostromal beds up to 2 m thick, the stromatoporoids indicating deposition of fine-grained sediments (Wilson, 1975). Flugel (1982) stated that in the Devonian bulbous stromatoporoids were prominent in back reef and back bank environments. In the absence of any indication of reefal fabrics in the carbonates, it is interpreted that these sediments were deposited in a back bank environment. The limestones interbedded in sub-unit F represent therefore a shoaling upward sequence from quiet lagoonal to a more active, wave-influenced environment. Enos (1983) suggested that the wave base in lagoonal settings is 4-5 m; the stromatoporoid-bearing sediments must therefore have been deposited above this depth.

Fauna and Age

The age of sub-unit F is based on the brachiopod *Buchanathyris* (GR 701 674 — identified by Dr A. J. Wright); *Spinella*, *Atrypa*, several unidentified spiriferids, a gastropod, bulbous stromatoporoids, *Favosites*, solitary corals, bryozoans, crinoid ossicles and at least one species of trilobite are also present. *Buchanathyris* is suggestive of a Zlichovian age (Wright, 1985, pers. comm.).

Buckaroo Conglomerate

The Buckaroo Conglomerate (Wright, 1966) is the oldest Late Devonian unit in this area, overlying Early Devonian strata with angular unconformity. The upper part of this unit is gradational with the Bumberra Formation, the contact being marked by a rapid decrease in the abundance of pebble- and granule-sized lithic fragments. The Buckaroo Conglomerate is distinguished by its dominance of a coarse sandy matrix and patchy reddish coloration, due to abundant hematite in the matrix. The unit crops out in two areas, a western block running between GR 660 700 and GR 690 650 and in a prominant syncline in the NE of the area (e.g. at GR 680 695), where it has an average thickness of 150 m.

Petrography

The dominant lithology of this unit is pebbly sandstone with minor conglomeratic bands, as well as subordinate sandstone and shale. The coarser horizons tend to be tightly packed, very poorly sorted, texturally mature and contain sub-angular to sub-rounded acid volcanic clasts and subordinate metaquartzite fragments in a coarse to very coarse sand matrix. As with the other siliciclastic units in the study area, the Buckaroo Conglomerate is stronglv silica cemented.

Environment of Deposition

The presence of medium-scale (up to 0.5 m) tabular cross-stratified pebbly sandstone with clasts up to several centimetres in size is indicative of high energy conditions, and may be generated in either a fluviatile or near shore marine environment. However, the intense bioturbation commonly exhibited by shallow marine shales (Reading, 1978) is not evident in the shales of the Buckaroo Conglomerate; nor would the massive beds of shale (up to several metres thick) be expected to be preserved in the high energy environment necessary to produce a near shore conglomerate.

The presence of large scale, up to 2 m, fining-upward sequences is indicative of a fluvial depositional environment. These sequences begin with a basal, densely packed conglomerate and proceed upward into cross-bedded pebbly sandstone, then coarse sandstone. The sequences may occasionally be capped by a thin shale. The dominance and coarseness of the bed-load sediment, as well as the presence of the fining-upward sequences suggests that the Buckaroo Conglomerate was deposited in a braided fluviatile environment. Similar braided fluviatile sequences have been described by Rust (1984). Relatively few palaeoflow measurements were collected; they are reasonably uniform however, and indicate a northerly flow for the palaeoriver.

Fauna and Age

The Buckaroo Conglomerate has been considered Late Devonian (Wright, 1966) as it is conformably overlain by the Bumberra Formation, which near Mudgee contains *Cyrtospirifer*. However, no fossils were found in this unit in the area of study and the existing age is accepted.

Bumberra Formation

The Bumberra Formation (Wright, 1966) conformably overlies the Buckaroo Conglomerate, the gradational boundary between the two only being able to be placed to within 10 m. The unit is a sequence of buff to light grey, fine-grained sublitharenite up to 1060 m thick, which crops out in two separate areas; one is about GR 690 650 forming part of a faulted block of Late Devonian strata, while near GR 690 710 the second forms part of a large syncline composed only of Late Devonian units.

Petrography

The unit is composed of tightly packed, poorly sorted, texturally mature to submature with subrounded to rounded grains averaging in size from fine to medium sand. However, occasional lithic clasts up to 1.5 cm are scattered throughout the unit, especially near the base. Quartz grains constitute up to 81% of this lithology, while lithic clasts, dominated by cherty acid volcanics vary between 6.0 and 13.0% of the rock. These grains and clasts are set in a sericite-rich, silica cement. Flattened, angular mud flakes up to 3 cm in size are also found throughout the unit.

Environment of Deposition

The presence of marine brachiopods near the base of the Bumberra Formation indicates marine conditions existed during deposition of the unit. The gradational nature of the contact with the fluviatile Buckaroo Conglomerate would also indicate a gradation from fluvial to marine conditions. As such the Bumberra Formation, at least near its base, must have been deposited in very near shore conditions.

The formation consists of basically two lithologies. The first is massive, fine-grained sandstone beds up to 20 cm thick. The second is fine-grained, finely internally laminated sandstone, the laminae defined by thin layers of hematite and tourmaline. The second lithotype occasionally exhibits medium-scale cross-bedding and low (up to 2 cm high) ripples on bedding planes. This latter lithology is interpreted as representing periods of low energy, with long shore drift currents occasionally becoming sufficiently strong to produce the ripples and cross-bedding. The massive beds are the result of wave generated disruption of the laminated horizons. The absence of shale in the sequence would indicate that this disruption occurred very near shore, and was the result of fair weather wave activity.

Fauna and Age

The fauna of the Bumberra Formation in this area is extremely limited, containing bryozoans, bivalves and *Cyrtospirifer*. The presence of *Cyrtospirifer* indicates a Late Devonian age for the unit (Wright, 1985, pers. comm.).

Lawsons Creek Shale

The Lawsons Creek Shale was proposed by Wright (1966), for a sequence of 'thinly interbedded grey or buff shales and siltstones which crop out about Lawsons Creek between Mt. Frome and Mt. Knowles'. In the study area the unit crops out at GR 687 660, where it occurs in a NW-SE trending belt that forms part of a Late Devonian fault block. This unit consists of over 225 m of thinly bedded, coarse silts and shales. Beds vary in thickness from 2 mm to several centimetres.

The unit appears to conformably overlie the Bumberra Formation, as it does elsewhere. The contact however is not exposed. Wright (1966) reported that the Lawsons Creek Shale is overlain by the Derale Sandstone to the north of the study area.

Petrography

This unit consists of two main lithologies, the first being an immature, very finely laminated, coarse, silty quartzarenite with a buff to reddish colour. The dominant component of the lithology is sub-rounded to rounded quartz grains up to 0.07 mm, the remainder consisting of sericite and hematite, the latter forming thin stringers and lineations defining bedding. The second lithology is a very thinly bedded, greenish coloured shale. The dominant and largest component of the shales is sub-rounded to rounded quartz grains in the coarse silt range. These quartz grains are set in a matrix dominated by sericitic mica showing a preferred orientation parallel to bedding. Scattered amongst the sericite are larger (up to 0.05 mm) grains of detrital biotite.

Environment of Deposition

The brachiopod fauna described from this unit by Wright (1966) is indicative of a marine environment of deposition. Reading (1978) stated that most extensive muds are only preserved in water depths in excess of 30 m, due to the effects of wave action. The presence of silty horizons within the shale (this study and Wright, 1966) is probably due to mobilization of the silt by storm wave activity, its transport and subsequent deposition in the shelf muds that represent the majority of the Lawsons Creek Shale. Wright (1966) suggested that the unit becomes increasingly sandy and considerably thicker to the south of Cudgegong, suggesting that this probably reflects increasing proximity to the palaeoshoreline.

Fauna and Age

Although no fossils were found in this area, Wright (1966) identified brachiopods in this unit in the Mudgee area, of which *Mucrospirifer* and *Cyrtospirifer* are indicative of a Late Devonian age.

Rylstone Tuff

The Rylstone Tuff was named after a series of rhyolites and dacites cropping out near the township of Rylstone. The unit crops out extensively in the NE corner of the study area, between GR 710 670 and GR 710 713, continuing well to the east.

The tuff, while exhibiting a slight dip to the NE on its western margin, is generally flat lying. It overlies the Devonian with a pronounced angular unconformity best exposed between GR 693 704 and GR 695 707. The Rylstone Tuff is overlain by Permian sediments of the Sydney Basin elsewhere in the Mudgee region (Day, 1961; Offenburg *et al.*, 1971). However, in the study area this relationship cannot be confirmed as the two sequences do not come into contact. Day (1961) suggested a maximum thickness of 300 ft (100 m) for the unit, but only approximately 50-60 m of section is exposed in the study area.

The sequence is lithologicaly varied, a well-bedded, discontinuous, 1 m thick air-fall tuff (lithology B of Fig. 4) near its base (at GR 699 702), while near the top of the section (GR 692 707) a laterally discontinuous, distinctive, 2 m thick conglomerate containing trough cross-beds up to 6 m across is present. The combination of large scale trough cross-beds, rounded nature of the composite clasts and high content of sandstone and shale clasts suggests that the conglomerate originated from fluvial reworking of the tuff. The bulk of the sequence is composed of massive, very loosely packed, lithic rich tuff, containing very angular, rhyolitic clasts. This lithology is interpreted as a stacked sequence of ash-flow deposits.

Petrography

The fluvially reworked conglomerate is cream to greenish, very poorly sorted, loosely packed and texturally submature with clasts dominantly in the granule to boulder size range, set in a greenish cherty silica matrix. The clasts are mostly angular to sub-angular in shape and rhyolitic, although abundant sub-angular quartz sandstone and shale clasts are also present.

The massive, lithic-rich tuff (lithology A of Fig. 4) is white, poor to very poorly sorted, containing abundant loosely packed, angular clasts of rhyolite and quartzite set in an abundant devitrified glassy matrix. The air-fall tuff (lithology B of Fig. 4) on the other hand is a white, well bedded rock, mostly composed of glass, occasional glass shards and quartz grains and thin horizons (1-2 mm thick) of densely packed quartz grains.

Age and Origin

The Rylstone Tuff has been dated radiometrically by Shaw *et al.* (1989) at 292 Ma. If the 286 Ma. age assigned to the Carboniferous-Permian boundary by Harland *et al.* (1982) is accepted then the Rylstone Tuff is Stephanian in age. However, recently both Lippolt *et al.* (1984) and Gulson *et al.* (1990) have suggested 300 Ma. and 299 Ma. respectively as the age of the boundary. The latter authors are followed here, with an age of ca 300 Ma. being adopted for the Carboniferous-Permian boundary, making the Rylstone Tuff basal Permian.

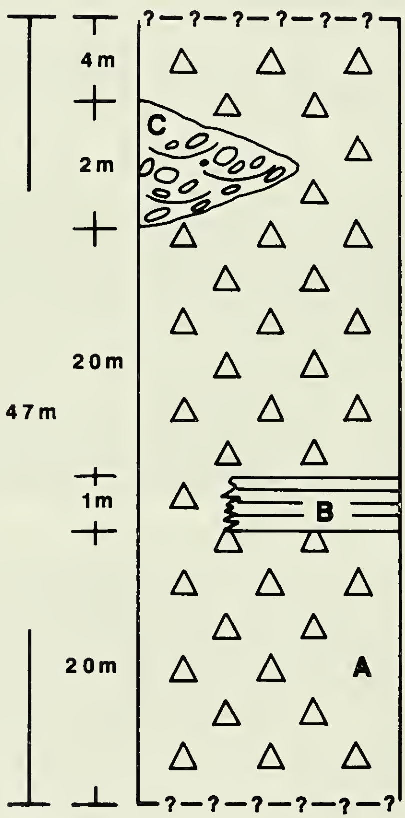

Fig. 4. Generalized stratigraphic section (diagrammatic) through the Rylstone Tuff; in the vicinity of GR 692 707 to GR 700 702. (A) Possible ash-flow tuffs, (B) Air-fall tuff, (C) Fluvially reworked conglomerate.

There appear to have been several periods of plutonism during the Late Carboniferous and Early Permian of eastern Australia. The first was associated with a phase of plutonism that lasted from approximately 325-310 Ma. (Powell, 1984: fig. 204), and resulted in the emplacement of granites such as the Gulgong Granite (312 Ma.; Evernden and Richards, 1962) and Aarons Pass Granite (320-322 Ma.; Vicary, 1983). The second, and younger, major period of volcanism was associated with the initiation of the Bowen-Sydney Foreland Basin in the Permian. Shaw *et al.* (1989) suggested that the origins of the Rylstone Tuff lay with this period of volcanism. Veevers (1984: 239) however suggested that the oldest volcanics associated with the onset of this basin development are the Hillgrove Suite (289 Ma.) and Bundarra Suite (286 Ma.), post-dating the tuff by ca 3-6 Ma. Veevers (1984) also mentioned an intermediate transitional phase of volcanism represented by the Bulganunna Volcanics (297 Ma.) and coeval granites (296 Ma. on average), pre-dating the Rylstone tuff by ca 4-5 Ma. Due to the error margins implicit in these radiometric dates, and the similarity in the age obtained for the Rylstone Tuff with those of both the intermediate and basin initiation phases of volcanism it remains unclear with which of these two phases of volcanism the tuff is associated. It is evident that the origins of the Rylstone Tuff are more closely associated with the inception of the development of the Bowen-Sydney Basin than with the Kanimblan Orogeny, as has been suggested in the past.

Megalong Conglomerate

Flat-lying erosional remnants of Permian conglomerate crop out very poorly in the study area, being best developed further to the east (near Rylstone) and to the south of Cudgegong. The unit forms the base of the Early Permian Shoalhaven Group. The sequence is exposed at GR 665 710 as well as between GR 677 703 and GR 686 711, but is best developed at GR 686 716. At GR 686 716 the unit reaches a thickness of 2-3 m, but in other areas it occurs only as scattered lag deposits on the tops of hills above 650-680 m above sea level. The unit overlies the older Palaeozoic sequence with angular discordance, on an undulatory erosional base.

The unit is dominated by polymictic conglomerate and pebbly sandstone with abundant rounded, cherty and rarer sandstone clasts up to 5 cm in size. Many of the clasts have been derived from older strata exposed in the Mudgee region, *Cyrtospirifer*-bearing clasts being abundant elsewhere in the conglomerate.

STRUCTURE

Folding

Folds in Devonian strata in the study area are shallowly plunging ($<30°$), with axes trending NW-SE between 129° and 174°. Although there does not appear to be a consistent difference in the trend of folds deforming only Early Devonian strata and those deforming Late Devonian strata, examination of the style of macroscopic folds may distinguish two groups of folds. The folds deforming Early Devonian units tend to be tight to moderately tight, concentric and asymmetrical with rounded to square hinge domains (best developed in the SE of the area). Those folds deforming Late Devonian strata are similar to those deforming the Early Devonian, except that their hinges are rounded and the folds appear to be symmetrical. However, the only macroscopic example of this fold style is exhibited by the Late Devonian syncline occupying the NE part of the study area. The style of deformation described above is illustrated in a series of cross-sections (see Fig. 5).

Faulting

Two separate sets of faults can be recognized. The older and more extensive set has approximately NW-SE trends; parallel to major fold axes, and the same orientation as the major faults in the Mudgee region. The younger group has SW-NE to approximately east-west trends, and can dislocate the previously mentioned faults, as well as apparently being of smaller scale.

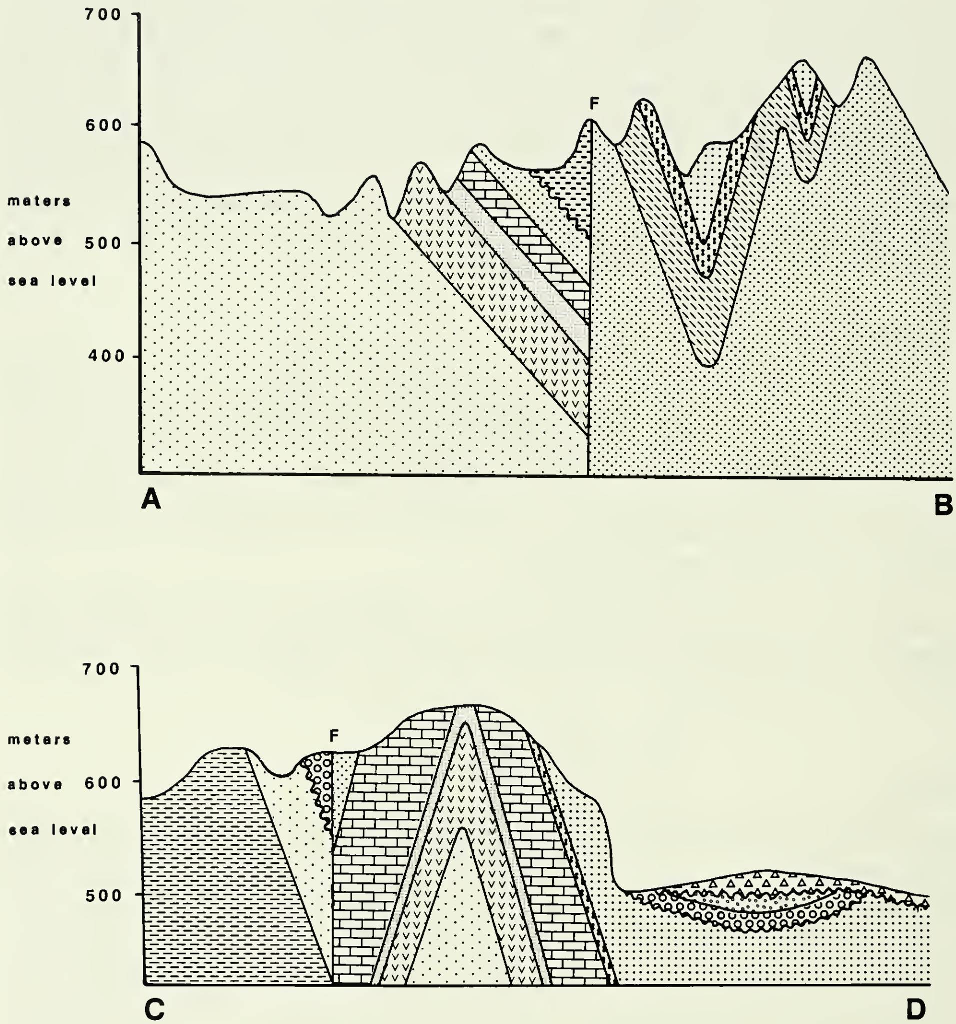

Fig. 5. Cross-sections through the study area, showing structural relationships. See Fig. 2 for the locations of sections.

The most important of the older set of faults exposed in the study area is the Cudgegong Fault. This structure is important because it forms the western margin of the easternmost fault block in Fig. 3. The Cudgegong Fault is a westerly dipping structure, as is shown by the relationship of its trace to the topography (this study) and the occurrence of westerly dipping slickensides to the south of Cudgegong (Pemberton, 1977).

The major faults in the region dislocate Late Devonian strata but are overlain by Permian sediments (the Megalong Conglomerate). It is therefore suggested that their formation was associated with the Carboniferous Kanimblan Orogeny. The age of the second, east-west to NE-SW trending, group of faults is similarly constrained as they dislocate the NW-SE trending faults but are overlain by the Megalong Conglomerate.

Geological History

During the Mid-Silurian (Wenlockian) the Capertee High was initiated as part of the horst and graben system that also formed the Cowra Trough, Hill End Trough and Molong High (Powell, 1984). This was followed by a period of shallow marine to terrestrial carbonate and clastic sequences (Wright, 1966, 1967, 1969; Packham, 1968).

The area underwent a period of tectonism during the Late Silurian to Early Devonian, this being the Bowning Orogeny (Cas, 1983). Associated with this tectonism (during the Pridolian to Lochkovian) a line of volcanoes developed along the Capertee High (Powell, 1984). These erupted dacitic and rhyolitic material into shallow marine conditions, and gave rise to the Windamere Volcanics.

The Lochkovian Yellowman's Creek beds and younger (?Pragian) Roxburgh Formation were also deposited in very shallow marine conditions, with water depths mostly between 4-5 m and 15-20 m.

Deposition of the Riversdale Volcanics in the ?Pragian represents renewed volcanicity on the Capertee High. Following sedimentation of the Riversdale Volcanics, the Carwell Creek beds were deposited in shallow marine conditions with water depths varying between 5 and 30 m, with the majority deposited in water less than 20 m deep.

The inferred environments of deposition of Early Devonian strata suggest water depths less than 30 m, with no evidence of sub-aerial exposure. This would indicate that during the Early Devonian the area was undergoing either transgression or subsidence, with a rate equal to that of sedimentation.

The angular unconformity between the Carwell Creek beds and the Late Devonian strata proves that the area was affected by the Middle Devonian Tabberabberan Orogeny (see Packham, 1960; Webby, 1972; Scheibner, 1973; Matson, 1975; Powell and Edgecombe, 1978). The low angle of discordance between the two sets of strata suggests that the effects of the orogeny were only mild in the study area. Wright (1967, 1969) found no evidence at Mt Frome, near Mudgee, of an unconformable relationship between Middle and Late Devonian strata, and concluded that the Tabberabberan Orogeny had not affected the Mudgee area.

The Late Devonian sequence represents a marine transgressional period following the Tabberabberan Orogeny, indicating either subsequent subsidence of the palaeohigh following cessation of the uplift associated with the mid-Devonian orogeny or a rise in sea level. This transgression is marked by the progressive change from terrestrial to lower shoreface facies and finally to a transitional (neritic) facies.

The Devonian and older strata were deformed into NW-SE trending folds by the Carboniferous Kanimblan Orogeny, which also produced the major fault structures observed, as well as cratonizing the Lachlan Fold Belt.

Following the Kanimblan Orogeny in the Early Carboniferous (Powell, 1984) there was emplacement of granitic bodies such as the Aaron's Pass Granite. This was followed in the earliest Permian by deposition of the Rylstone Tuff, approximately coinciding with the initiation of the Sydney Basin development. Later in the Early Permian, the deposition of the Megalong Conglomerate occurred on the edge of the Sydney Basin, in response to the subsidence of that basin (Matson, 1975).

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